UNIVERSITI PUTRA MALAYSIA

REMOVAL OF OIL FROM OIL PALM EMPTY FRUIT BUNCHES SPIKELET USING STEAM AND WATER PROCESSES

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By

JAVIER HERNANDO CHAVARRO GOMEZ

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the requirements for the degree of Master of Science

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DEDICATION

To my beloved parents, who have support, guide and have been an example on each step on my life

"Ana Tulia Gomez de Chavarro and Hernando Chavarro Rozo"

My sister who always have believe in me,

"Luz Angela Chavarro Gomez"

Also to my Nephew and Nice,

'"Juan Jose Uruena Chavarro" and "Montserrat Uruena Chavarro"

And finally to my lovely Sanitaz

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

REMOVAL OF OIL FROM OIL PALM EMPTY FRUIT BUNCHES SPIKELET USING STEAM AND WATER PROCESSES

By

JAVIER HERNANDO CHAVARRO GOMEZ

DECEMBER 2014

Chairman: Mohd Noriznan Mokhtar, PhD, Ing

Faculty: Engineering

The development of new low cost technologies to increase the oil recovery in the palm oil mill especially from the palm oil wastes has been an important goal for the industry to increase oil extraction performance. In addition to the crude palm oil (CPO) production, high amount of wastes are annually generated at the mill with remainedCPO attached to them. The empty fruit bunches (EFB) is the largest solid wastes produced and high amount of oil it is impregnated due to mechanical processes during CPO extraction. However, the EFB is thrown in the field without further processing. Initially, the EFB was analyzedto determine initial oil content.Then, the detection and identification of oil were performed using Sudan Red to achieve an insightful view of oil that located inside and on the surface of EFBspikelet. The study shows that the oil mainly located on the surface of spikelet, about 73.73 ± 0.05 % from total residual oil. Furthermore, the comparison of oil recovery efficiency among processes using saturated steam, hot water, combined steam-water, combined water-steam and high pressure spray water and steam was carried out. As a result of this work, two methods showed the best oil extraction yield, indicating that over 88% and 92% of oil could be removed from theEFB spikelet by hydro solvent assisted extraction (HYSASE) and high pressure fluid spray system (HPFSS), respectively. Finally, the quality of oil that obtained by HYSASE and HPFSS was compared with the quality of oil that obtained from shredded and pressed EFB, indicating almost similar oil quality, except for PV, with the advantage

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that more oil could be recovered.The recovered residual oil probably is not suitable as edible oil on its own or to be blended with CPO obtained from the main process at the palm oil mill. However, it has potential to be used as a feedstock for biodiesel, bio-lubricant production and other applications. Thus, these methods provide non-chemical, environmental friendly and novel processes of residual CPO recovery from EFB.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENYINGKIRAN MINYAK DARIPADA SPIKELET TANDAN BUAH KOSONG KELAPA SAWIT MENGGUNAKAN PROSES WAP DAN AIR

Oleh

JAVIER HERNANDO CHAVARRO GOMEZ

DISEMBER 2014

Pengerusi: Mohd Noriznan Mokhtar, PhD, Ing.

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Pembangunan teknologi baru kos rendah untuk meningkatkan pemerolehan minyak di kilang minyak sawit terutama dari sisa kelapa sawit telah menjadi satu matlamat penting bagi industri untuk meningkatkan kadar perahan minyak. Pengesanan dan pengenalpastian minyak telah dilakukan dengan menggunakan Sudan Merah untuk mencapai pandangan yang jelas terhadapminyak yang terdapat di dalam dan di permukaan spikelet tandan kosong.Kajian menunjukkan bahawa kebanyakan minyak terletak di permukaan spikelet, kira-kira 73.73 ± 0.05% daripada jumlah sisa minyak.Perbandingan kecekapan pemerolehan minyak antara proses-proses yang berbeza iaitu menggunakan stim tepu, air panas, gabungan stim-air, gabungan air-stim dan semburan air dan stim bertekanan tinggi telah dilakukan. Hasil daripada kajian ini, dua proses telah menunjukkan hasil perolehan minyak yang terbaik, lebih daripada 88% dan 92% daripada minyak boleh dikeluarkan daripada spikelet EFB dengan masing-masing menggunakan pengekstrakan terbantu pelarut hidro (HYSASE) dan sistem semburan cecair bertekanan tinggi (HPFSS). Kualiti minyak yang diperolehi oleh HYSASE dan HPFSS telah dibandingkan dengan kualiti minyak yang diperolehi daripada proses pencarikan dan tekanan EFB, dimana iamenunjukkan kualiti minyak yang hampir sama, kecuali PV, dengan kelebihan lebih banyak minyak diperolehi. Minyak tertinggal yang telah diasingkan mungkin tidak sesuai sebagai minyak untuk makanan atau boleh dicampur dengan minyak sawit mentah yang diperolehi daripada proses utama di kilang. Walau bagaimanapun, ia mempunyai potensi untuk digunakan sebagai bahan mentah untuk biodiesel, pengeluaran bio-pelincir

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dan aplikasi lain. Oleh itu, kaedah ini melibatkan proses bukan kimia dan mesra alam dalam pemerolehan minyak sawit mentah daripada EFB.

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APPROVAL

I certify that a Thesis Examination Committee has met on _____ to conduct the final examination of Javier Hernando Chavarro Gomez on his thesis entitled **Residual oil recovery from oil palm empty fruit bunch by applying water and steam processes**in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science

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This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as filfulment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follow:

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TABLE OF CONTENTS

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LIST OF TABLES

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LIST OF FIGURES

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LIST OF ABBREVIATIONS

CPO	Crude palm oil
KPO	Kernel palm oil
OER	Oil extraction rate
POME	Palm oil mill effluent
OPT	Oil palm trunks
EFB	Empty fruit bunche
FFB	Fresh fruit bunche
HHV	High heating value
VOC	Volatile organic compounds
RORS	Residual oil recovery system
SPEFB	Shredded and pressed EFB
SC-CO_2	Super critical carbon dioxide
HYSASE	Hydro solvent assisted extraction
HPWSS	High pressure water steam system
FFA	Free fatty acids
DOBI	Deterioration of bleachability index
PV	Peroxide value

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CHAPTER 1

INTRODUCTION

1.1 General Background

Palm oil is one of the most consumed vegetable oils worldwide. Palm oil industry is the largest agro industry in Southeast Asian countries. In 2007, the world production of vegetable oil was estimated to 121 Mt, including palm oil, soya bean oil, rapeseed oil and sunflower seed oil (Corley, 2009). Palm oil, which is a variety of vegetable oil, is extracted from the fruit of the perennial oil palm tree, and represents over 30.5% of the world total production of vegetable oils, followed by soybean with 29%. The crude palm oil production has been led by Asian countries such as Indonesia and Malaysia by producing over 90% of the world requirement and around 75% of it is traded internationally (Oosterveer, 2014).

One of the biggest crude palm oil (CPO) producers such as Malaysian depends mostly on the international market which has been increasing in the last few years. Among other oil palm products traded, the palm oil exports have shown an increase from 2008 to 2013, with 15 Mt and 18.1 Mt, respectively (MPOB, 2014a). The Malaysian annual CPO production also increased during this period from 15 Mt in 2007 to 19 Mt in 2013 (MPOB, 2014b), which has established Malaysia as the second largest crude palm oil producer in the world just behind Indonesia with over 30 Mt in 2013.This increasing demand of palm oil is due to its multiple usages such as for edible consumption, bio-chemical industry and nowadays, oleo chemistry. Due to the diversity of usage and the high demand, the production of palm oil continues to increase annually.

Although the expansion of palm oil production has boosted the national economies of Malaysia and Indonesia, the rapid growth of the agro-industry has also given rise to significant environmental and social concerns. For instance, the exploration of rain forests and other territories in Malaysia and Indonesia has been discontinued and oil palm plantation expansion has been limited, thus restraining the increase of crude palm oil production (Wicke et al., 2011). Nowadays, the crude palm oil industry has diverted its efforts to increasing the oil production by optimizing the process rather than focusing on agricultural expansion.

The oil extraction rate (OER) has been used as an indicator of the efficiency of oil recovery from the extraction process. The OER compares the ratio of palm oil produced per day, with the total fresh fruit bunches supplied per day (Husain et al., 2003). According to Balasundram et al. (2006), it was

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found that the oil content was over 30% in the commercial variety of oil palm *elaeisguineensis*. However, the OER was estimated to be as much as 20.3% in 2013 (MPOB, 2013c). This indicates that a high amount of oil was lost during the extraction process in the form of biomass that produced during the extraction process.

1.2 Problem statements

Wastes such as palm oil mill effluent (POME), oil palm trunks (OPT), decanter cakes and empty fruit bunches (EFB) are produced as biomass. Most of these residues are used as animal feed, compost or merely burnt, with a significant amount of oil still remains inside biomass. Thus, the disposal of biomass without proper treatment not only causes high oil losses but also causes several environmental problems. The EFB is the largest solid waste produced after the milling process, and it was estimated that over 20 Mt was produced in Malaysia in 2012 (MPOB, 2013d).

Due to the interaction of fresh fruit bunches (FFB) with mechanical process such as loading sterilizer cages, sterilization, and stripping of the fruit, a portion of the CPO is impregnated mainly on the EFB. According to Ma (2005), the oil content on the EFB has been estimated to be as much as 0.75 to 8.5% dry basis and is located mainly on the spikelet rather than on the stalk.

Nowadays, some efforts to recover the remaining oil from the produced wastes have been made. The use of solvent extraction, which is one of the oldest extraction methods has been widely studied. However, new environmental regulations require the use of safer and cleaner methods. The use of super-critical fluid extraction to recover the remaining oil from mesocarp has yielded high recovery rates. However, high capital investment prohibits its implementation at the mill. On the other hand, the mechanical process, shredding and pressing has also been employed. According to Jorgensen (1985) the EFB is shredded and then pressed is not only to extract the remaining oil but also to reduce storage space. This method recovered just 1.5% wet basis of the remaining oil from EFB. Additionally, due to the strong fibres present in the EFB, the shredding blades must be frequently maintained and replaced, thus increasing operational cost. Currently this process is considered as conventional method.

In light of the above, this study focuses on the recovery of oil from EFB using water and steam by applying different techniques. This study also highlights the efficiency of oil removal by comparing water, steam and combinations of both processes. Along these lines, two novel and environmental friendly processes were developed to recover oil from EFB using water and steam, which are available resources in the mill.

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The objectives of this study are:

1) To evaluate and to choose suitable water and steam processes to recover the crude palm oil that remained on the oil palm empty fruit bunches.
2) To study the performance of high pressure fluid spray systemcompared with the most suitable method from objective (1), in order to recover the residual oil from the oil palm empty fruit bunches.

Scope of the thesis

The aim of this thesis is to provide an understanding of the removal of remained oil inEFB by applying novel and environmental techniques using water and steam. The first chapter is the introduction to the oil production and the amount of oil lost in the form of biomass during the extraction of CPO. Moreover, in this chapter it is explained the disadvantages of the current technology used at the palm oil mill and the problem that can be solved by utilizing environmental friendly processes.

In chapter two, thespecific details of the world CPO production and grow estimation it is presented. Furthermore, the benefits and disadvantages of currents techniques used for the recovery of oil from different oil material such as corps, empty fruit bunches and petroleum based sources are explained. Finally, the advantages of the method proposed for the recovery of CPO from EFB is explained and a brief description of the availability of water and steam at the mill is included.

The methodology used during the experimental work is explained in chapter 3. In this chapter different chemicals and materials such as extraction chamber, pressure equipment, soxhlet and soxtec, metalab oil quality tester, etc., used during the experimental work are explained. Also, analytical procedures such as detection of oil, oil content, oil quality, oil recovery, etc., used to compare the efficiency among removal processes are explained in detail. In addition, the methodology used for the removal of oil by using water and steam process is explained.

Chapter 4 shows the efficiency of oil removal that obtained after applying water and steam processes. In this chapter, the oil recovery and oil removal of oil was compared among processes. Moreover, the visualization of the oil attached to the spikelet before treatment was conducted by applying Sudan red under UV light. This procedure was repeated after the removal process to compare the removal efficiency. Also, the inner and surface layer of the spikelet was analysed by SEM in order to understand the morphology of the EFB fibers. Finally, the results of oil quality obtained from different processes

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such as palm mill, shredded and press, hydro solvent assisted extraction and high pressure fluid spray system are presented and compared.

Finally in Chapter 5 the conclusion of the presented work are shown. The comparison between the objective proposed during the research and the results obtained after the research are shown. Also, in this chapter the benefits of novel, high efficient and environmental friendly processes for the recovery of CPO from EFB are presented which can highly increase the revenue of the mill.

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